

What is claimed is:

1. A system for high-precision determination of the angular position of a light beam in an optical scanning device, the system comprising:

a source of light that emits a substantially collimated primary light beam;

a light-sensitive sensor;

an optical element used to focus an image onto the sensor; and

a rotatable mirror system that re-directs the primary light beam to a plurality of locations of an external surface of a component, the rotatable mirror system comprising:

a rotary axis;

a mirror structure that rotates about the rotary axis;

at least one detector positioned to intercept a light beam that has been reflected off the mirror structure at an angle representing a start-of-scan such that a first trigger pulse is generated, and positioned to intercept a light beam that has been reflected off the mirror structure at an angle representing an end-of-scan such that a second trigger pulse is generated; and

an auxiliary system that provides measurement data between the start-of-scan angle and the end-of-scan angle;

wherein the first trigger pulse and the measurement data are used to determine the angular position of the primary light beam.

2. The system of claim 1, wherein the auxiliary system includes a measurement device which is coupled to the rotary axis, and wherein the first and second trigger pulses and the measurement data are all used to determine the angular position of the primary light beam.

3. The system of claim 2, wherein the measurement device is at least one item selected from the group consisting of a potentiometer, an optical encoder, a magnetic encoder, a resolver, a rotary variable differential transformer, and combinations thereof.
4. The system of claim 2, wherein the auxiliary system further includes a digital filter that smoothes the measurement data.
5. The system of claim 4, wherein the digital filter employs an adaptive nearest neighbor smoothing algorithm.
6. The system of claim 4, wherein the digital filter is selected from the group consisting of a windowed FIR filter, a wavelet filter, and combinations thereof.
7. The system of claim 4, wherein a spline or high-order polynomial is applied to the smoothed measurement data.
8. The system of claim 2, wherein the measurement data is adjusted using a fixed pattern offset error mapping function.
9. The system of claim 8, wherein the mapping function is derived from data which has been smoothed.
10. The system of claim 1, wherein the auxiliary system includes an auxiliary light-sensitive sensor and a beam splitter, wherein the beam splitter is positioned to intercept the primary light beam subsequent to reflecting off of the mirror structure, and wherein the beam splitter re-directs a portion of the primary light beam onto the auxiliary sensor.

11. The system of claim 1, wherein the auxiliary system includes an auxiliary light-sensitive sensor and a beam splitter, wherein the beam splitter is positioned to intercept the primary light beam prior to reflecting off of the mirror structure, and wherein the beam splitter re-directs a portion of the primary light beam onto the mirror structure which reflects the re-directed primary light beam portion onto the auxiliary sensor.

12. The system of claim 11, wherein the auxiliary system further includes a folding mirror which is positioned to intercept the re-directed primary light beam portion subsequent to reflecting off the mirror structure, wherein the folding mirror reflects the re-directed primary light beam portion directly onto the auxiliary sensor.

13. The system of claim 1, wherein the auxiliary system includes an auxiliary light-sensitive sensor and an auxiliary light source, wherein the auxiliary light source emits a substantially collimated auxiliary light beam onto the mirror structure which reflects the auxiliary light beam onto the auxiliary sensor.

14. The system of claim 13, wherein at least one of the first trigger pulse and the second trigger pulse is used as a fixed reference to the auxiliary light beam in determining the angular position of the primary light beam.

15. The system of claim 13, wherein the primary light beam is reflected off a portion of the mirror structure while the auxiliary light beam is simultaneously reflected off a different portion of the mirror structure.

16. The system of claim 10, wherein the auxiliary system further includes an imaging element which is positioned to intercept the re-directed primary light beam portion between the beam splitter and the auxiliary sensor.

17. The system of claim 11, wherein the auxiliary system further includes an imaging element which is positioned to intercept the re-directed primary light beam portion between the mirror structure and the auxiliary sensor.
18. The system of claim 13, wherein the auxiliary system further includes an imaging element which is positioned to intercept the auxiliary light beam between the mirror structure and the auxiliary sensor.
19. The system of claim 16, wherein the imaging element comprises a substantially telecentric element.
20. The system of claim 17, wherein the imaging element comprises a substantially telecentric element.
21. The system of claim 18, wherein the imaging element comprises a substantially telecentric element.
22. The system of claim 10, wherein the auxiliary sensor comprises a PSD type sensor.
23. The system of claim 11, wherein the auxiliary sensor comprises a PSD type sensor.
24. The system of claim 13, wherein the auxiliary sensor comprises a PSD type sensor.
25. The system of claim 10, wherein the auxiliary sensor comprises an array of auxiliary detectors arranged at predetermined angular intervals for generating a series of discrete trigger

pulses as the re-directed primary light beam portion sweeps across the array of auxiliary detectors, wherein the measurement data comprises the series of discrete trigger pulses.

26. The system of claim 11, wherein the auxiliary sensor comprises an array of auxiliary detectors arranged at predetermined angular intervals for generating a series of discrete trigger pulses as the re-directed primary light beam portion sweeps across the array of auxiliary detectors, wherein the measurement data comprises the series of discrete trigger pulses.

27. The system of claim 13, wherein the auxiliary sensor comprises an array of auxiliary detectors arranged at predetermined angular intervals for generating a series of discrete trigger pulses as the auxiliary light beam sweeps across the array of auxiliary detectors, wherein the measurement data comprises the series of discrete trigger pulses.

28. The system of claim 25, wherein the auxiliary system further includes a comparator, wherein the array of auxiliary detectors are configured such that the output of every other auxiliary detector within the array of auxiliary detectors is connected in common to an input of the comparator, and wherein the outputs of the remaining auxiliary detectors within the array of auxiliary detectors are connected in common to another input of the comparator.

29. The system of claim 26, wherein the auxiliary system further includes a comparator, wherein the array of auxiliary detectors are configured such that the output of every other auxiliary detector within the array of auxiliary detectors is connected in common to an input of the comparator, and wherein the outputs of the remaining auxiliary detectors within the array of auxiliary detectors are connected in common to another input of the comparator.

30. The system of claim 27, wherein the auxiliary system further includes a comparator, wherein the array of auxiliary detectors are configured such that the output of every other

auxiliary detector within the array of auxiliary detectors is connected in common to an input of the comparator, and wherein the outputs of the remaining auxiliary detectors within the array of auxiliary detectors are connected in common to another input of the comparator.

31. The system of claim 25, wherein the measurement data is adjusted using a fixed pattern offset error mapping function.

32. The system of claim 26, wherein the measurement data is adjusted using a fixed pattern offset error mapping function.

33. The system of claim 27, wherein the measurement data is adjusted using a fixed pattern offset error mapping function.

34. The system of claim 31, wherein the mapping function is derived from data which has been smoothed.

35. The system of claim 32, wherein the mapping function is derived from data which has been smoothed.

36. The system of claim 33, wherein the mapping function is derived from data which has been smoothed.

37. The system of claim 16, wherein the auxiliary system further includes an aperture mask, wherein the auxiliary sensor comprises an auxiliary bi-cell detector which has a first half and a second half separated by a dividing line oriented along the direction that the re-directed primary light beam portion sweeps, wherein the aperture mask is positioned to intercept the re-directed primary light beam portion between the beam splitter and the auxiliary bi-cell detector, wherein a

first row of the aperture mask includes a pattern of alternating transparent and opaque regions, wherein a second row of the aperture mask includes another pattern of alternating transparent and opaque regions which are identical but out of phase to the regions of the pattern of the first row of the aperture mask, wherein the first row of the aperture mask alternately passes a first portion of the re-directed primary light beam portion to the first half of the auxiliary bi-cell detector as the re-directed primary light beam portion sweeps along the aperture mask, wherein the second row of the aperture mask alternately passes a second portion of the re-directed primary light beam portion to the second half of the auxiliary bi-cell detector as the re-directed primary light beam portion sweeps along the aperture mask, and wherein alternating variations of the received intensities detected by the first and second halves of the auxiliary bi-cell detector are used to create discrete trigger pulses, wherein the measurement data comprises the discrete trigger pulses.

38. The system of claim 17, wherein the auxiliary system further includes an aperture mask, wherein the auxiliary sensor comprises an auxiliary bi-cell detector which has a first half and a second half separated by a dividing line oriented along the direction that the re-directed primary light beam portion sweeps, wherein the aperture mask is positioned to intercept the re-directed primary light beam portion between the mirror structure and the auxiliary bi-cell detector, wherein a first row of the aperture mask includes a pattern of alternating transparent and opaque regions, wherein a second row of the aperture mask includes another pattern of alternating transparent and opaque regions which are identical but out of phase to the regions of the pattern of the first row of the aperture mask, wherein the first row of the aperture mask alternately passes a first portion of the re-directed primary light beam portion to the first half of the auxiliary bi-cell detector as the re-directed primary light beam portion sweeps along the aperture mask, wherein the second row of the aperture mask alternately passes a second portion of the re-directed primary light beam portion to the second half of the auxiliary bi-cell detector as the re-directed primary light beam portion sweeps along the aperture mask, and wherein alternating variations of

the received intensities detected by the first and second halves of the auxiliary bi-cell detector are used to create discrete trigger pulses, wherein the measurement data comprises the discrete trigger pulses.

39. The system of claim 18, wherein the auxiliary system further includes an aperture mask, wherein the auxiliary sensor comprises an auxiliary bi-cell detector which has a first half and a second half separated by a dividing line oriented along the direction that the auxiliary light beam sweeps, wherein the aperture mask is positioned to intercept the auxiliary light beam between the mirror structure and the auxiliary bi-cell detector, wherein a first row of the aperture mask includes a pattern of alternating transparent and opaque regions, wherein a second row of the aperture mask includes another pattern of alternating transparent and opaque regions which are identical but out of phase to the regions of the pattern of the first row of the aperture mask, wherein the first row of the aperture mask alternately passes a first portion of the auxiliary light beam to the first half of the auxiliary bi-cell detector as the auxiliary light beam sweeps along the aperture mask, wherein the second row of the aperture mask alternately passes a second portion of the auxiliary light beam to the second half of the auxiliary bi-cell detector as the auxiliary light beam sweeps along the aperture mask, and wherein alternating variations of the received intensities detected by the first and second halves of the auxiliary bi-cell detector are used to create discrete trigger pulses, wherein the measurement data comprises the discrete trigger pulses.

40. The system of claim 10, wherein the auxiliary system further includes a light pipe, wherein the light pipe is positioned to intercept the re-directed primary light beam portion, wherein the light pipe comprises at least two mirrors having a gap therebetween, wherein the re-directed primary light beam portion is transmitted through the gap at varying pointing angles as the re-directed primary light beam portion sweeps, wherein at one of the varying pointing angles the re-directed primary light beam portion is reflected off one of the at least two mirrors onto the



auxiliary sensor, and at at least one other of the varying pointing angles the re-directed primary light beam portion is reflected off at least one other of the at least two mirrors onto the auxiliary sensor, resulting in at least two discrete trigger pulses at the auxiliary sensor, wherein the measurement data comprises the at least two discrete trigger pulses.

41. The system of claim 11, wherein the auxiliary system further includes a light pipe, wherein the light pipe is positioned to intercept the re-directed primary light beam portion, wherein the light pipe comprises at least two mirrors having a gap therebetween, wherein the re-directed primary light beam portion is transmitted through the gap at varying pointing angles as the re-directed primary light beam portion sweeps, wherein at one of the varying pointing angles the re-directed primary light beam portion is reflected off one of the at least two mirrors onto the auxiliary sensor, and at at least one other of the varying pointing angles the re-directed primary light beam portion is reflected off at least one other of the at least two mirrors onto the auxiliary sensor, resulting in at least two discrete trigger pulses at the auxiliary sensor, wherein the measurement data comprises the at least two discrete trigger pulses.

42. The system of claim 13, wherein the auxiliary system further includes a light pipe, wherein the light pipe is positioned to intercept the auxiliary light beam, wherein the light pipe comprises at least two mirrors having a gap therebetween, wherein the auxiliary light beam is transmitted through the gap at varying pointing angles as the auxiliary light beam sweeps, wherein at one of the varying pointing angles the auxiliary light beam is reflected off one of the at least two mirrors onto the auxiliary sensor, and at at least one other of the varying pointing angles the auxiliary light beam is reflected off at least one other of the at least two mirrors onto the auxiliary sensor, resulting in at least two discrete trigger pulses at the auxiliary sensor, wherein the measurement data comprises the at least two discrete trigger pulses.

43. The system of claim 40, wherein the light pipe is positioned to intercept the re-directed primary light beam portion between the beam splitter and the auxiliary sensor.
44. The system of claim 41, wherein the light pipe is positioned to intercept the re-directed primary light beam portion between the mirror structure and the auxiliary sensor.
45. The system of claim 42, wherein the light pipe is positioned to intercept the auxiliary light beam between the mirror structure and the auxiliary sensor.
46. The system of claim 40, wherein the auxiliary system further includes a folding mirror positioned at an end of the light pipe which is opposite an entrance of the light pipe, wherein the folding mirror folds the path of the re-directed primary light beam portion within the light pipe, and wherein the auxiliary sensor is positioned at the entrance of the light pipe.
47. The system of claim 41, wherein the auxiliary system further includes a folding mirror positioned at an end of the light pipe which is opposite an entrance of the light pipe, wherein the folding mirror folds the path of the re-directed primary light beam portion within the light pipe, and wherein the auxiliary sensor is positioned at the entrance of the light pipe.
48. The system of claim 42, wherein the auxiliary system further includes a folding mirror positioned at an end of the light pipe which is opposite an entrance of the light pipe, wherein the folding mirror folds the path of the auxiliary light beam within the light pipe, and wherein the auxiliary sensor is positioned at the entrance of the light pipe.
49. The system of claim 40, wherein the gap is tapered so as to control the angular occurrence of the discrete trigger pulses.

50. The system of claim 41, wherein the gap is tapered so as to control the angular occurrence of the discrete trigger pulses.
51. The system of claim 42, wherein the gap is tapered so as to control the angular occurrence of the discrete trigger pulses.
52. The system of claim 11, wherein the auxiliary system further includes a diffractive element which is positioned to intercept the re-directed primary light beam portion at the surface of the mirror structure resulting in a series of diffracted beams, wherein the series of diffracted beams sweeps across the auxiliary sensor as the mirror structure rotates resulting in a corresponding series of discrete trigger pulses, wherein the measurement data comprises the corresponding series of discrete trigger pulses.
53. The system of claim 13, wherein the auxiliary system further includes a diffractive element which is positioned to intercept the auxiliary light beam at the surface of the mirror structure resulting in a series of diffracted beams, wherein the series of diffracted beams sweeps across the auxiliary sensor as the mirror structure rotates resulting in a corresponding series of discrete trigger pulses, wherein the measurement data comprises the corresponding series of discrete trigger pulses.
54. The system of claim 52, wherein the diffractive element comprises a compensative configuration so as to compensate for varying intensities of the series of diffracted beams.
55. The system of claim 53, wherein the diffractive element comprises a compensative configuration so as to compensate for varying intensities of the series of diffracted beams.

56. The system of claim 11, wherein the auxiliary system further includes a beam creating element which is positioned to intercept the re-directed primary light beam portion between the beam splitter and the mirror structure thereby resulting in a series of beams, wherein the series of beams are subsequently reflected off the mirror structure and sweep across the auxiliary sensor as the mirror structure rotates resulting in a corresponding series of discrete trigger pulses, wherein the measurement data comprises the corresponding series of discrete trigger pulses.

57. The system of claim 13, wherein the auxiliary system further includes a beam creating element which is positioned to intercept the auxiliary light beam prior to reflecting off the mirror structure thereby resulting in a series of beams, wherein the series of beams are subsequently reflected off the mirror structure and sweep across the auxiliary sensor as the mirror structure rotates resulting in a corresponding series of discrete trigger pulses, wherein the measurement data comprises the corresponding series of discrete trigger pulses.

58. The system of claim 56, wherein the beam creating element comprises a diffractive element.

59. The system of claim 57, wherein the beam creating element comprises a diffractive element.

60. The system of claim 56, wherein the beam creating element comprises a holographic element.

61. The system of claim 57, wherein the beam creating element comprises a holographic element.

62. The system of claim 56, wherein the beam creating element comprises a reflective element.
63. The system of claim 57, wherein the beam creating element comprises a reflective element.
64. The system of claim 56, wherein the auxiliary system further includes at least one optical collection element which is positioned to intercept the series of beams between the beam creating element and the mirror structure.
65. The system of claim 57, wherein the auxiliary system further includes at least one optical collection element which is positioned to intercept the series of beams between the beam creating element and the mirror structure.
66. The system of claim 1, wherein the mirror structure includes a plurality of primary mirrors positioned substantially concentrically surrounding the rotary axis.
67. The system of claim 1, wherein the mirror structure oscillates about the rotary axis with a torsional motion.
68. The system of claim 1, wherein each of the at least one detector is a bi-cell detector.
69. The system of claim 25, wherein the array of auxiliary detectors comprises an array of bi-cell detectors.
70. The system of claim 26, wherein the array of auxiliary detectors comprises an array of bi-cell detectors.

71. The system of claim 27, wherein the array of auxiliary detectors comprises an array of bi-cell detectors.